Towards sustainable architecture and urbanism through responsible tourism and the realization of zero-emission hotels

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Abstract

In the tourism sector, particularly in hotels, generally much more resources per guest are consumed than in residential buildings per inhabitant. Tourists generally want to enjoy free time and don't want primarily save resources. Accordingly the development and application of resource efficient and convenient so-called "zero-emission" concepts in hotels, can contribute to the saving of resources, such as energy, fresh water and nutrients. Good practice examples can function as role models for integrated urban resource management and contribute to increased awareness and distribution of knowledge regarding such systems. This paper discusses new decentralized approaches for the integrated management of resources, which can be applied in the tourism sector as well as in urban renewal projects and new urban developments. Recent developments in the cities Hamburg and Berlin (Germany, EU) are used as examples to discuss the potentialities for integrated system - and zero emission approaches related to urban tourism.

Keywords: zero-emission, hotel, resources, management, sustainability.

Introduction

Growing urbanization, increasing resource consumption and climate change require increasing adapting capacity of the urban environment, for example to droughts, floods and heat waves, more sustainable use (and reuse) of resources as well as the adaptation of urban infrastructure systems. Many cities are expected grow and to be the main human habitat in the next decades. While currently already more than 50% of the world population lives in cities, it is expected that in 2030 approx. 70% will do so. The urbanization rate exceeds the global population growth, resulting in rural exodus and shrinking rural population. In the framework of the urbanization process 29 urban agglomerations are expected to become mega cities in 2025 (United Nations, 2009). With growing urbanization also the "city tourism" has increased in the past decades, with rising tendency. In the period from 1995 to 2020 worldwide long-haul travel is expected to grow at 5.4 per cent, and intraregional travel at 3.8 per cent per year. East Asia, the Pacific, Asia, the Middle East and Africa are forecasted to record higher growth at rates of over 5% year, than the world average of 4.1%. The top three regions will be Europe with arrivals of 717 million tourists, East Asia and the Pacific with 397 million tourists and the Americas with 282 million visitors, followed by Africa, the Middle East and South Asia. (World Tourism Organization, 2001)

The tourism sector and particularly hotels, generally consume more resources per guest than inhabitants in dwellings. Hotels aim to provide good services to guests who generally want to enjoy their free time and enjoy luxury and don't want primarily save resources. Accordingly the tourism sector is a good example for the challenges in cities, to achieve a sustainable management of natural resources while providing good services to inhabitants. The main important and increasingly pressing challenges in cities will be sustainable management and provision of natural resources, including the safe and adequate supply of water for city dwellers, particularly in developing countries. The growing city populations require increased drinking water supplies and the demand for more food is related with more water needed for food production and processing operations. Growing agricultural activities also in urban and peri-urban areas result in increasing demands for irrigation water as well as fertilizers and fertile soils. The growing pressure on the environment and the need for urban energy, water and food supplies require new and innovative alternatives to creating more resilient cities. Integrated urban water resource management, including rainwater harvesting, the recycling of wastewater, as well as the recovery of nutrients and the processing of organic waste holds for example a great potential for (urban) agriculture, but is as yet relatively untapped. "Meanwhile, good agriculture and forestry practices can contribute to sound watershed management, safeguarding water catchment and reducing runoff and flooding in cities - ever more important as climate change increases the frequency of extreme weather events" (FAO, 2011).

The development of sustainable resource efficient and convenient so-called "zero-emission" concepts, particularly for city hotels, could stimulate sustainable urban development, regarding both physical and social aspects. In European countries where city tourism, including for example cultural tourism and business tourism, have an important share in the entire tourism market, the gross occupation of accommodation facilities is quite equally distributed over the year, with peaks from April/May and to September/October. (European Communities, 2008) The resource flows in city hotels are therefore quite equally distributed over the year, allowing for permanent operation of the required management systems. The operation of new and innovative systems for resource management in the mainstream tourist sector, including conventional hotels and public toilets, offers the possibility to introduce systems which are based on the principles of a closed loop recycling economy to all classes of the society and preparing the ground for an area wide awareness, acceptance and distribution. Furthermore the application of sustainable resource management systems in the tourism sector can function as an advantage in competition because there is remarkable consumer awareness and growing demand for environmentally sound tourism, as stated in the following research results (in: The International Ecotourism Society, 2006 & Chafe, 2005).

- More than 66% of U.S. American and Australian travelers as well as 90% of British tourists think that hotels are responsible for active protection of the environment and support of local communities.
- A portion of 20 to 30% of all travelers in Europe are aware of the needs and values of sustainable tourism while 10%-20% of travelers look for so called "green" options and 5 to 10% of travelers even demand "green" holidays. (Hamele, 2004)
- Approximately 65% (39 million) of all travelers in Germany expect environmental quality while 42% (25 million) "think that it is particularly important to find environmentally-friendly accommodation." (Hamele, 2002)
- Nearly half of the interviewees in Great Britain said they would prefer to book with company that guarantees good working conditions, protects the environment and supports local charities in the tourist destination. (Tearfund, 2000)
- A survey of travelers from the U.S., Britain, and Australia indicates that 70% of the tourist would pay up to $150 more for a 14 days stay in a hotel having a responsible environmental attitude. (Travelbiz, 2002)
- In a survey executed in the U.K., 87% of travelers stated that their holiday should not damage the environment and 39% said they would be prepared to pay 5% extra for ethical guarantees. (Ipsos, 2002)

Recent developments in the cities Hamburg and Berlin cities (Germany, EU) are used as examples to discuss the potentialities for integrated system - and zero emission approaches in tourism. In particularly a practical and built example for an integrated and decentralized resource management concept, including water, organic waste and energy, is developed for the new construction of hotel in the city centre of Berlin. In the framework of an integrated planning process for the building construction and the building service engineering, a so-called "ZERO-Emission-Hotel" is developed and planned by Wahl & Bauer Architects. The building concept is based on the principles of sustainability, which will be evaluated with life cycle assessment tools and certified with the system of the DGNB (German Green Building Council – Deutsche Gesellschaft fuer Nachhaltiges Bauen). Sustainable sanitation systems and a resource flow management system will be integrated in the building and in the existing urban infrastructure. The aim is to enhance the performance of urban energy, water, wastewater and organic waste management systems regarding sustainability criteria without any loss of comfort. The main elements of the integrated concept are amongst others:

- Significant reduction of the buildings service energy demand and water consumption for the transport of waste products, for example by the use of state of the art technology, such as water saving appliances, cascade uses and reuse and recycling measures.
- Separation of water-, resource-, and energy flows for efficient treatment and recycling. (Including: rainwater, greywater from bathrooms and kitchen, blackwater, organic waste, hot water production, heating, cooling and ventilation)
- Utilization of rain- and greywater for adiabatic cooling of the building, and restoration of the natural water balance, such as the enhancement of the local micro-climate by evaporation, reduction of runoff (flood control) and recharge of groundwater.

This paper discusses new decentralized approaches for the sustainable supply and integrated management of resources, which can be applied in the tourist industry as well as in urban renewal projects and new urban developments. The different sub-system and technologies, which will be installed in the "ZERO-Emission-Hotel", have been already developed in the last decade and are being operated and monitored for different periods. In the subsequent sections the systems and technologies as well as their specific properties and profits will be discussed. The application of different systems does not focus on specific tourism categories. However, the application of such environmental sound systems consequently results in facilities, which can be assigned to the categories "responsible" and "sustainable" tourism. According to Chafe (2005) responsible tourism "maximizes the benefits to local communities, minimizes negative social or environmental impacts, and helps local people conserve fragile cultures, habitats, and species". Sustainable tourism "meets the needs of present tourist and host regions while protecting and enhancing opportunities for the future".

Sustainable Water use and organic waste management

Water consumption in the tourist sector is generally significantly higher than in dwellings. In German households approximately 50 litres of drinking water are used per person and day in shower, bath and washbasin. In hotels an amount of 100 litres or even more is used in these facilities. Also the use for toilet flush, cleaning and laundry is in hotels generally quite high, due to daily laundry and cleaning services and the required procedure to flush the toilet for that purpose. Accordingly huge quantities of water could be saved with technologies allowing for fresh water savings and water recycling. A first step for the reduction of water consumption is the installation of water saving toilets and so-called "flow rate delimiters" for shower and bathtub, which allow for instance in households a reduction of the freshwater consumption by approximately 30% without loss of comfort. (Schuetze, 2005 & Schuetze et al., 2008)

Dependent on the type and costs for the substitution of standard appliances such water saving measures are achievable without or low additional costs, if they are installed in the framework of new installations in place of standard appliances. Accordingly, the zero-emission-hotel in Berlin will be equipped with water saving appliances and flow rate delimiters. Water saving taps (with flow rates of 3 litres per minute), showerheads (with flow rates of less than 5 litres per minute) and toilets (with flush volumes of 2, respectively 3.5 litres per flush) will allow minimal savings of approximately 50% compared with standard water saving appliances.

Greywater recycling: Additional savings in fresh water consumption can be achieved by the application of water recycling measures. A profitable and practically proven approach is the decentralized recycling of so-called "greywater" with low pollutant levels from shower and bathtub to service water which can be used for applications which don't require drinking water quality, such as toilet flushing, irrigation and/or laundry. The advantage of the decentralized collection and processing of greywater and the direct reuse of the produced service water (for example on building or block level) is the comparable small infrastructure, consisting of collection and supply pipes which is required for its installation. Furthermore it offers potentials for heat recovery as discussed in the following section.

In 1996 Europe's first big scale greywater recycling facility was realized for the 400 beds Arabella Sheraton 4 star hotel in Offenbach/Main (Germany). The installation whose function is based on biological treatment by means of a rotating trickling filter only occupies the space of two car-parking places in the underground parking lot of the hotel. The recycled greywater from shower and bath is recycled and reused (as so-called "service water") in the hotel for toilet flush; the surplus of recycled water is used for irrigation. The pay back period for investment, operation, service and maintenance costs of this quite expensive pilot installation (72,000 Euro) was only 6.5 years. Accordingly, the system is economically profitable since more than 8 years. The maintenance of the facility takes only two hours per month and once a year an overall system-check is executed. In average 3,700 m^3 drinking water could be saved per year, resulting in savings of 18,500 Euro for drinking water and sewage fee per year (approximately 5 Euro per m^3). The electric energy consumption of the grey water recycling facility including the distribution of service water is approx. 1-1.5 kWh. During the past 15 years, since the installation of the described facility, the technology for greywater recycling facilities has been further developed, resulting in lower system costs and enhanced control and monitoring systems.

Since 2007 a modern combined greywater-recycling and rainwater utilization system is installed in the five stars hotel with conference facilities "Elbresidenz" located at the river Elbe in Bad Schandau (Germany). 380 guests can be accommodated in the hotel. The greywater from shower and bath is recycled in a facility with a treatment capacity of 2.8 m^3 per day. The service water consisting out of recycled greywater and collected rainwater is used for toilet flush. The surplus is used for irrigation and infiltrated in the surrounding soils. The expected payback period for the combined facility is 6.6 years and is therefore comparable with the previously described facility in Offenbach. The monitoring and control of contemporary facilities for water recycling can be executed by the company, which also produces and installs the facility, providing therefore an overall service guarding against system failures. (Kionka, 2008) The installation of greywater recycling facilities requires the separate collection of the sewage streams from bathtub and shower as well as the installation of a separate service water supply system. Compared with the overall system costs and the achievable savings the costs for such a system are comparable low (Schuetze, 2005). The separated collection and treatment of greywater facilitates also the recycling of energy, which will be discussed in the following section "Energy Efficiency"

Based on the experiences from previous projects, the zero-emission hotel in Berlin will be equipped with a combined greywater recycling and rainwater collection and management facility, which is expected to be economically profitable. The separated greywater from showers and bathtubs will be collected separately and be processed to service water in the basement of the building. The service water will be used for toilet flush and irrigation of the green roof and garden. Surplus water will be infiltrated and recharge the groundwater. With the described measures it is expected that the quantity of consumed fresh water as well as of discharged sewage can be reduced by more than 50% compared with conventional hotels. It is planned to manage all rainwater on the property. The small amount of sludge originating from the biological greywater treatment process will be collected and processed together with the separated solids from blackwater processing and collected organic wastes (see subsequently "Blackwater and organic waste processing").

Yellowwater collection: The separation of yellowwater (urine) at the source offers a big potential for the optimization of existing wastewater management systems as well as for the design of new sustainable water and sanitation systems, which are based on the principles of Integrated Resource Management and a Closed Loop Recycling Economy. 80-90% of the total Nitrogen and 40-50% of the Phosphorous in domestic wastewater originate from urine. A big portion of precious nutrients such as Phosphorous and Nitrogen can therefore be theoretically separated from the sewage stream, supporting on the one hand the conventional sewage treatment process and allowing on the other hand the collection and reuse of urine. (Schuetze, 2010) The separated collection of all urine would be beneficial for water pollution control because the eco-toxicological hazard posed by human medicines in domestic wastewater (so called micro pollutants) could be reduced by approximately 50%. (Larsen, 2007) Furthermore also the partly separation of urine could already turn a wastewater treatment plant from an energy consumer into an energy producer. (Wilsenach, 2006) A complete nutrient removal in sewage treatment plants could be achieved already with a urine separation portion of 75% (Wilsenach, 2003). However, practical experiences with urine separation show that the separated collection of urine with waterless urinals works well and is convenient to use, while the separation with so-called "separation" or "no-mix" toilets is still a challenging task. (Lüthi et al., 2011) The most important problem is the correct use of such toilets by non-acquainted users. New users have therefore to be well informed about the proper use of the toilets. For an optimal operation a close collaboration with the maintenance service provider proved to be a critical factor for optimal operation in the framework of a three-years operation and monitoring phase of no-mix toilets in the "Forum Chriesbach" in Switzerland (Goosse, 2009). The water consumption of separation toilets available on the market is (with 6 litres per flush) similar to conventional watersaving toilets and therefore quite high compared with cutting-edge water saving non-separating toilets, which are available with flush volumes of only 3.5 litres or less for the big flush.

According to the previously discussed concerns regarding urine separation toilets, such toilets will not be installed in the zero-emission hotel in Berlin. Instead waterless urinals for the separate collection of urine will only be installed in the men's toilets assigned to the restaurant and conference facilities. In the other toilets, e.g. in the hotel rooms conventional cutting-edge water saving toilets will be installed. The yellowwater from urinals will be collected by means of a separate drainage pipe system and stored intermediately in containers, located in the basement of the hotel building. In specific intervals the filled urine containers will be replaced by empty ones and be transported to a central treatment facility for further treatment and reuse as fertilizer or the production of black fertile soil (so-called "Terra Preta", Portuguese for "black soil") together with other ingredients such as organic wastes and charcoal.

Experiences with yellowwater collection show that in drainage systems with open ventilation pipes approximately 50% of the ammonia contained in urine evaporates and gets lost through the ventilation system (Goosse, 2009). The yellowwater collection and storage system for the zero-emission hotel will therefore be equipped with an newly developed and enhanced system which is based on a drainage system with minimized drainage pipe diameters and contact between the urine and air. The ventilation valves of the system will always be closed during system operation. Additionally, ammonia evaporation losses will be avoided through the collection and storage of urine in a specially designed tank consisting out of a flexible bag to be filled from the bottom and not containing a worth mentioning air volume. Compared with the greywater recycling system, which is expected to be economically profitable, the separated collection of urine will presumably produce additional costs because there is not yet a market available for yellowwater. However it is planned to investigate in future how such productive and environmental sound sanitation systems can be integrated in a suitable fee system and a closed loop recycling economy. Through the installation of conventional but water saving flush toilets, a big part of the urine can't be collected separately. However a system allowing for the recovery of a mentionable amount of valuable substances and nutrients from blackwater, which is described in the subsequent section, will be installed in the hotel.

Blackwater and organic waste processing: The separate collection of blackwater allows the filtration and recovery of the majority of the contained organic solids and a mentionable part of the nutrients. These substances can be used as resources for the production fertile black soil. The remaining filtrate has a reduced pollution load and can be easier cleaned than untreated blackwater from toilets. Such blackwater filtration systems have been originally developed as much promising alternatives for septic tanks and are known as "rotte" or "pre-composting" treatment facilities (Schuetze, 2005). In the framework of recent research and development projects in Germany filtration systems for blackwater have been further developed and are successfully applied and operated. In a public toilet facility in the central train station of the city of Hamburg, a separated blackwater drainage, filtration and solid collection system has been installed and operated for a period of more than one year. In the same facility also waterless urinals are installed, facilitating the separate collection of undiluted urine. The experiences and findings from the separated urine and blackwater collection and treatement systems in Hamburg are also used for the planning and system optimization of the blackwater and organic waste processing system which will be installed in the zero-emission hotel in Berlin.

The blackwater from toilets is lead through a slit strainer originally developed as grease separator for kitchens ("TeceBASIKA-filter"). A spiral conveyor transports the separated solids (mainly faeces and toilet paper) automatically to a storage tank where it is mixed with a specific portion of porous charcoal powder and liquid EM (Effective Microorganisms), determined by the weight of filtered solids. The mixture of these ingredients results in a lactic acid fermentation process already taking place during the intermediate anaerobic storage in the container. No gas and no malodour are emitted. Full containers with a pre-fermented product are transported to a central facility for the production of Terra Preta. In 2011 parts of the collected and fermented solids were transported to the Botanical Garden in Berlin (Germany) where they were used in the framework of the research project "TerraBoga" (http://www.terraboga.de) for the production of Terra Preta and its use in urban agriculture.

The Terraboga research project is built on the findings that the production of this anthropogenic soil (which has been originally produced by cultures in the Brazilian amazon basin) is based on a lactic acid fermentation process, which incorporates human and/or animal wastes, organic material as well as charcoal. The nutrients (Nitrogen and Phosphorous) contained in the faeces are bound to the charcoal particles and stay in the soil until they are made available to the roots of plants by microorganisms. Due to this property, sufficient amounts of Terra Preta facilitate permanent rich plant growth without the need to use artificial fertilisers, and can contribute to the purification of rainwater runoff, also in case of heavy precipitation events, even though it is rich in nutrients. The good water storage facilities help to cope with floods and periods of drought and can therefore be used for the adaptation to the effects of climate change. Furthermore, this soil stores carbon (opposed to soils which are used for conventional agriculture and release carbon to the atmosphere) and contributes therefore to climate change mitigation (Factura et al., 2010).

Scientists developed different recipes for the contemporary production of Terra Preta, and to use its much promising properties for multiple purposes, such as the restoration of destroyed topsoil, organic horticulture and reforestation, as well as the management of urban organic waste. Black soil can be produced centrally, collective and also on individual level and is therefore applicable in almost all environments. The lactic acid fermentation is driven by Effective Microorganisms (EM), which can be either bought or be collected from healthy soils in the area of application (Park, 2008). The bio-charcoal for its production can be produced by pyrolysis of dry organic matter, such as waste material from agriculture or wood. This process facilitates both the production of Bio-Char and the production of heat and power through the burning of the occurring pyrolysis gas.

As so far only the solid matter from blackwter can be used for Terra Preta production, the remaining blackwater filtrate is discharged to the public sewer systems in both cases, the public toilet in the central train station in Hamburg as well as the zero-emission-hotel. Theoretically this wastewater fraction could be also treated on-site and be reused, but due to the comparable small quantity, the related effort and the mandatory requirement to connect the drainage systems to the public sewer system, it has been decided to discharge the filtered blackwater to the sewer system. However, in the framework of the Terraboga research projects it is investigated, if the charcoal, which is required for the fermentation process, could be previously used to absorb nutrients form the blackwater filtrate. Based on the findings in the public toilet in the central train station in Hamburg, it is expected that almost 90% of the faces and the toilet paper can be separated with the slit strainer. Accordingly also the biggest part of the contained nutrients can be separated and reused for the production of fertile soil (Thomas, et al., 2011).

Dependent on the portion of separated urine it can be estimated that more than 50% of the total Phosphorous and 10% of the total Nitrogen contained in the wastewater stream of the zero-emission hotel can be collected and processed for reuse in Terra Preta. Compared with the greywater recycling system, which is expected to be economically profitable, the separated processing of blackwater will presumably produce additional costs because there is not yet a market available for products made from blackwater. However it is planned to investigate in future how such productive sanitation systems can be integrated in a suitable fee system an a closed loop recycling economy.

In the zero-emission hotel in Berlin the filtered solids from blackwater will be collected in containers and pre-fermented with charcoal and EMs together with the organic wastes from the hotel restaurant, allowing for efficient storage, transport and further processing to Terra Preta. It is planned to use the resulting soil for biomass production. As long as there are concerns regarding the security of food grown with Terra Preta made from human faeces, it is planned to use it for the enhancement of soils in urban horticulture, which is not meant for human consumption (such as in parks and gardens). However, it is expected that the Terraboga research project will deliver results, which will be useful for the evaluation of Terra Preta regarding their specific properties also related to human health aspects. A much promising approach for the application of Terra Preta is the production of biomass, such as fast turnover wood, for heat and electricity production, as discussed in the following section.

Energy efficiency and productivity

The energy efficiency of buildings is one of the most important environmental criteria for sustainable buildings because the energy consumption of conventional buildings during their lifetime is generally responsible for the biggest environmental impact. Heating, cooling and hot water production in the building sector is responsible for more than 1/3 of the total energy consumption in the EU while the total energy demand account for 40 % of total energy consumption in the Union. As the sector is expanding, also its energy consumption is increasing. Therefore, the reduction of the energy consumption and the use of energy from renewable sources are important measures needed to reduce the energy dependency and the greenhouse gas emissions in the EU. By 2021 all new buildings (public building already by 2019) in the EU have to be built as so-called "lowest energy buildings" with an energy demand of "zero" or "nearly zero" for heating, cooling and warm water production. The remaining energy demand has to be produced on the building or in the direct neighbourhood by means of renewable energy sources. Also in the framework of renovation of the existing building stock important measures for enhancing the energy efficiency are required (EU, 2010). Accordingly, from 2020 all new building projects should be energy neutral and regarding the consumption of non-renewable energy resources already "zero-emission" buildings.

The zero-emission hotel in Berlin is therefore also planned as a "lowest-energy-building" with minimized energy demand for heating, cooling and warm water production. Also the electricity demand for the operation of the building will be significantly reduced to limit the primary energy consumption for the operation of the hotel to 120 kW/m^2a. The measures, which will be taken to achieve good energy efficiency, are a well-insulated building envelope, the reduction of thermal bridges as well as the installation of a mechanical ventilation system with heat recovery. These measures are quite common for energy efficient buildings. Additionally new and innovative measures for energy efficiency will be applied which are based on the creation of synergies between the water and energy sector.

Using thermal energy from recycled greywater, rainwater and green roof: The previously described facility for the recycling of greywater will also be used for the recovery of heat from the processed greywater. Experiences with the heat recovery from greywater are available through a pilot installation of the so-called "Pontos Heat Cycle" in student apartments, which is still operating properly and has been monitored for a period of two years. The evaluation results are much promising. They indicate that greywater recycling is more profitable with heat recovery than without, both regarding environmental and economical aspects. By means of two heat exchangers the cold freshwater is pre-heated by the comparable warm greywater, before it is processed in the recycling facility. In yearly average approximately 20% of the energy required for the warm water production could be saved. (Vetter et al., 2011) To enhance the efficiency of the heat recovery system, the greywater recycling facility with heat recovery, which will be installed in the zero-emission hotel in Berlin, will have a different system layout. The greywater will be collected and purified in a thermally insulated recycling facility. Afterwards, the thermal energy in the processed but still warm service water will be extracted by means of a heat exchanger and a heat pump, facilitating theoretically a much higher heat recovery rate than with the Pontos Heat Cycle. It is expected that the biggest part of the warm water demand could be even covered by heat extraction from purified water by means of a heat pump alone.

After the heat extraction process it is planned to store the cooled service water in another thermally insulated tank equipped with another heat exchanger connected with the adiabatic cooling system of the hotel. During the hot summer months when cooling of the building maybe required to provide comfortable indoor temperatures, the cold water could be used for the building component activation of the floor slabs. Additional cooling capacity can be achieved by using the service water for irrigation and evaporative cooling of the hotels greened roof. As only a part of the hotel roof is greened, additional service water will be provided by means of rainwater, collected from the non-greened roof surfaces of the hotel. The cooling by means of service water evaporation on greened roofs can also be used to create synergies with renewable energy production, as described in the subsequent section.

Production of renewable energy: Renewable energy for the zero-emission- hotel in Berlin will by produced by photovoltaic modules, to be installed on the flat roof of the building. On the greened roof areas synergies between the photovoltaic energy production and the evaporative cooling with service water can be achieved. Due to a significant lower temperature of the intensively irrigated greened roof, the PV modules are expected to have a higher efficiency of 8-10% during hot summer days in comparison with modules, which are installed on conventional roofs (without evaporative cooling). Due to the comparable small roof surface area of the hotel the PV modules can only contribute partly to the renewable production of the energy required for the building service. As the building is located in the centre of Berlin and surrounded by relatively high buildings, the installation of Photovoltaic modules in the façades of the building was not regarded as productive.

Another renewable energy source, which will be used additionally to the PV generators, is near-surface geothermal energy, which will be extracted from the ground under the building. Due to the fact that near-surface geothermal energy (up to a depth of 100m) is stored solar energy, it is indeed renewable. The biggest part of the hotels remaining thermal and electrical energy demand during the winter will be covered by a combined heat and power (CHP) generator, which will use biogas as fuel. For the future it is desired to replace the gas burner with a CHP that can burn solid biofuels. These could for instance desirably originate from regional timber plantations to be grown on the basis of black soils produced from the hotels own organic wastes. In such a way a closed loop recycling economy could be realized on regional level. However, so far no small-size facilities for the combined heat and power generation from solid fuels are available on the market. However it is much promising that technologies which facilitate the production of thermal, and electric energy as well as the production of bio-charcoal at the same time, are currently in the focus of research projects executed by producers of CHP generators (Sterling DK, 2011). Such technology would indeed facilitate the creation of synergies between sustainable organic waste management, sanitation, as well as food and energy production and therefore prepare the ground for sustainable development.

Conclusions

According to the research results and projects described in the framework of this paper, it is feasible to realize urban infrastructures, which are contributing to sustainable architecture and urbanism by resource efficiency and the integrated management of water, energy and organic waste on regional level. The consumption of resources and the generation of wastes can be reduced significantly, resulting in both environmental and potential economical profits. The application of such systems is particularly important and feasible in the tourist sector, such as in hotels, because multiple aims can be achieved. The provision of good services and high comfort levels, which don't differ from conventional hotels, as well as transparent communication of implemented sustainability aspects to tourists, work as competitive advantage addressing both conventional tourists and guests looking for responsible and/or sustainable hosts. Such a (still) unique selling proposition can potentially result in higher occupation rates and related income. Savings in energy and fresh water consumption (e.g. by recycling of greywater with heat recovery) result in significant reduction of service costs for the operation of the hotel. After a comparable short pay back period of less than 10 years such systems can generate net savings and therefore an additional income compared with hotels without such installations (at least in areas which have drinking water and sewage fee structure which is similar to the German situation). The application of new and innovative systems for the management of faeces and organic waste and Terra Preta production, are still in the pilot and development phase. Markets for the generated end products have still to be developed and their monetary value to be determined. Accordingly no amortisation of the installation and operation costs of such systems can be achieved so far. However, this situation is similar to conventional and quite costly centralized systems for sewage treatment and organic waste management. Also these systems don't generate net income. They even have significant system immanent disadvantages because they don't facilitate the appropriate treatment and reuse of the different sewage streams (Schuetze, 2005). With complete decentralized wastewater and organic waste management systems, savings in central infrastructure systems could be achieved and investment could be shifted towards more sustainable infrastructure systems. In case of the zero-emission hotel in berlin such savings cannot be achieved because the building has to be connected to the public sewer system by law. However, the building owner, the catholic public organization "Ludwig-Wolker-Haus" plans to invest in the described new and innovative sustainable infrastructure systems. The organization believe having the responsibility to care spiritually and physically for the earth. Accordingly, the construction, operation, monitoring as well as accompanying research and promotion of the ZERO-Emission-Hotel in Berlin contributes significantly to the development of sustainable architecture and urbanism.

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